

The Search for the Neutron Electric Dipole Moment

Maurits van der Grinten (for the EDM coll.)

RAL/Sussex/ILL

Brighton
Sussex University



Rutherford Appleton
Laboratory



Grenoble
Institut Laue Langevin



The nEDM experiment at ILL:

- Measurement principle
- Experimental set-up
- Results - Statistics
- Main systematics

The Neutron Electric Dipole Moment: d_n

$d_n \neq 0 \Rightarrow P$ and T violation

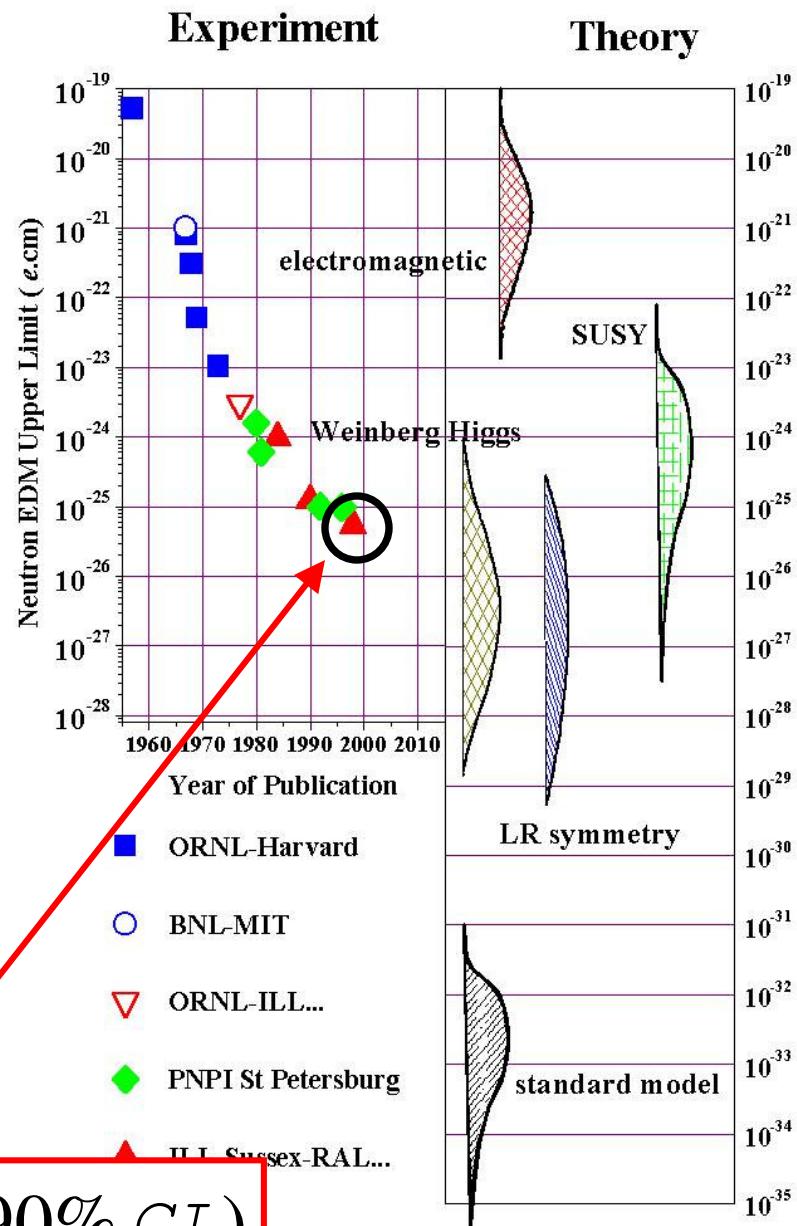
In Standard Model:
 $d_n \sim 10^{-32} e \text{ cm}$

Beyond Standard Model:
 $d_n \sim 10^{-26} - 10^{-29} e \text{ cm}$

nEDM very sensitive probe
for physics beyond SM

$d_n < 6.3 \times 10^{-26} e \cdot \text{cm}$ (90% CL)

The neutron EDM: exp. vs theory



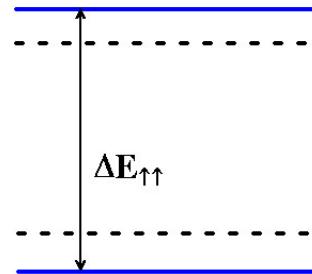
Experiments:

Measurement of Larmor precession frequency of polarised neutrons in a magnetic & electric field

$$\sigma(d_n) = \frac{\hbar}{2\alpha ET \sqrt{N}}$$

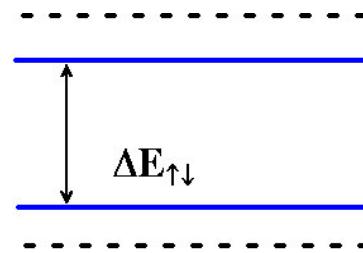
α : polarisation product
 E : electric field
 T : observation time
 N : number of neutrons

Compare the precession frequency for parallel fields:



$$v_{\uparrow\uparrow} = \Delta E_{\uparrow\uparrow}/h = [-2B_0\mu_n - 2Ed_n]/h$$

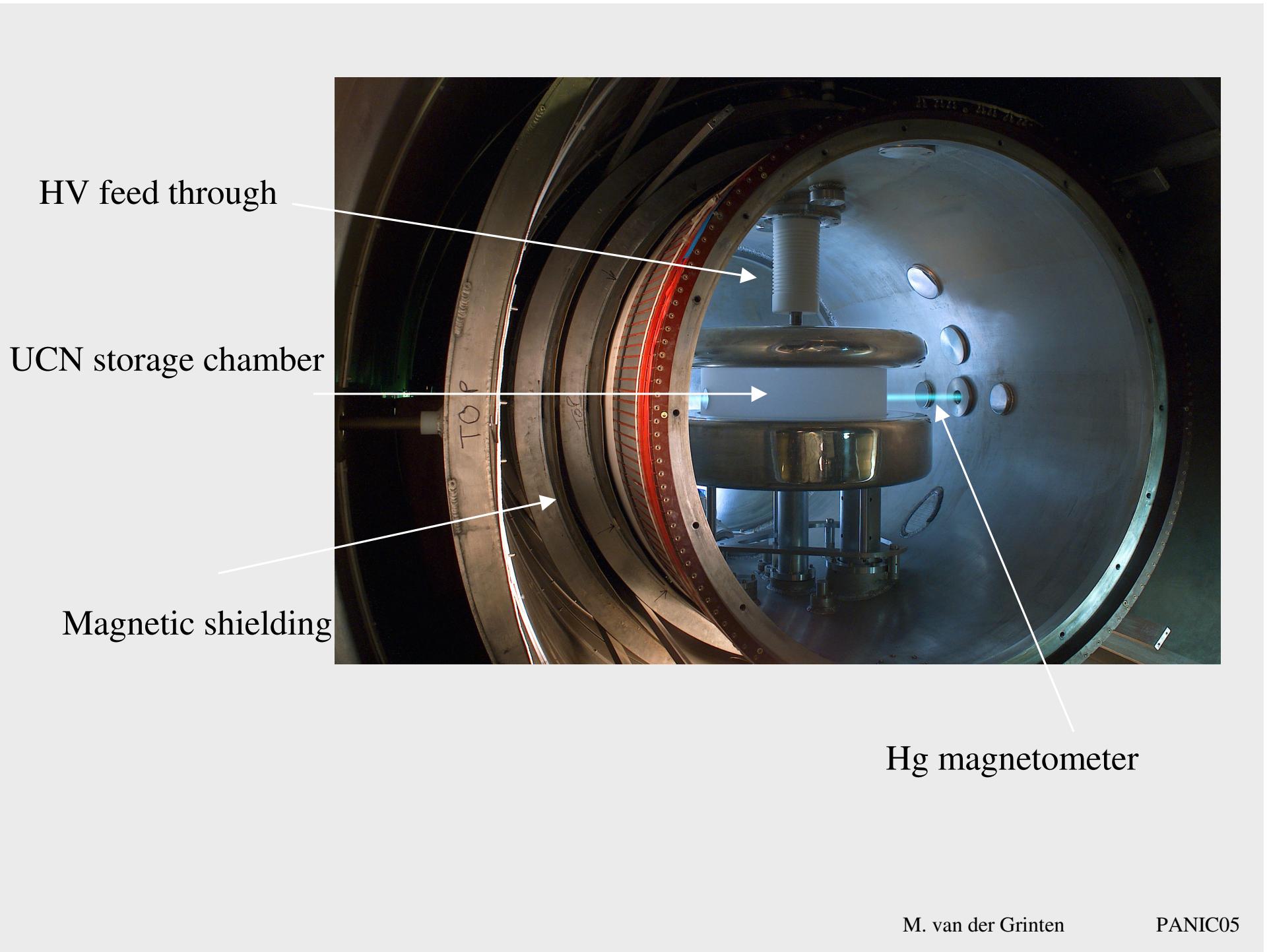
to the precession frequency for anti-parallel fields



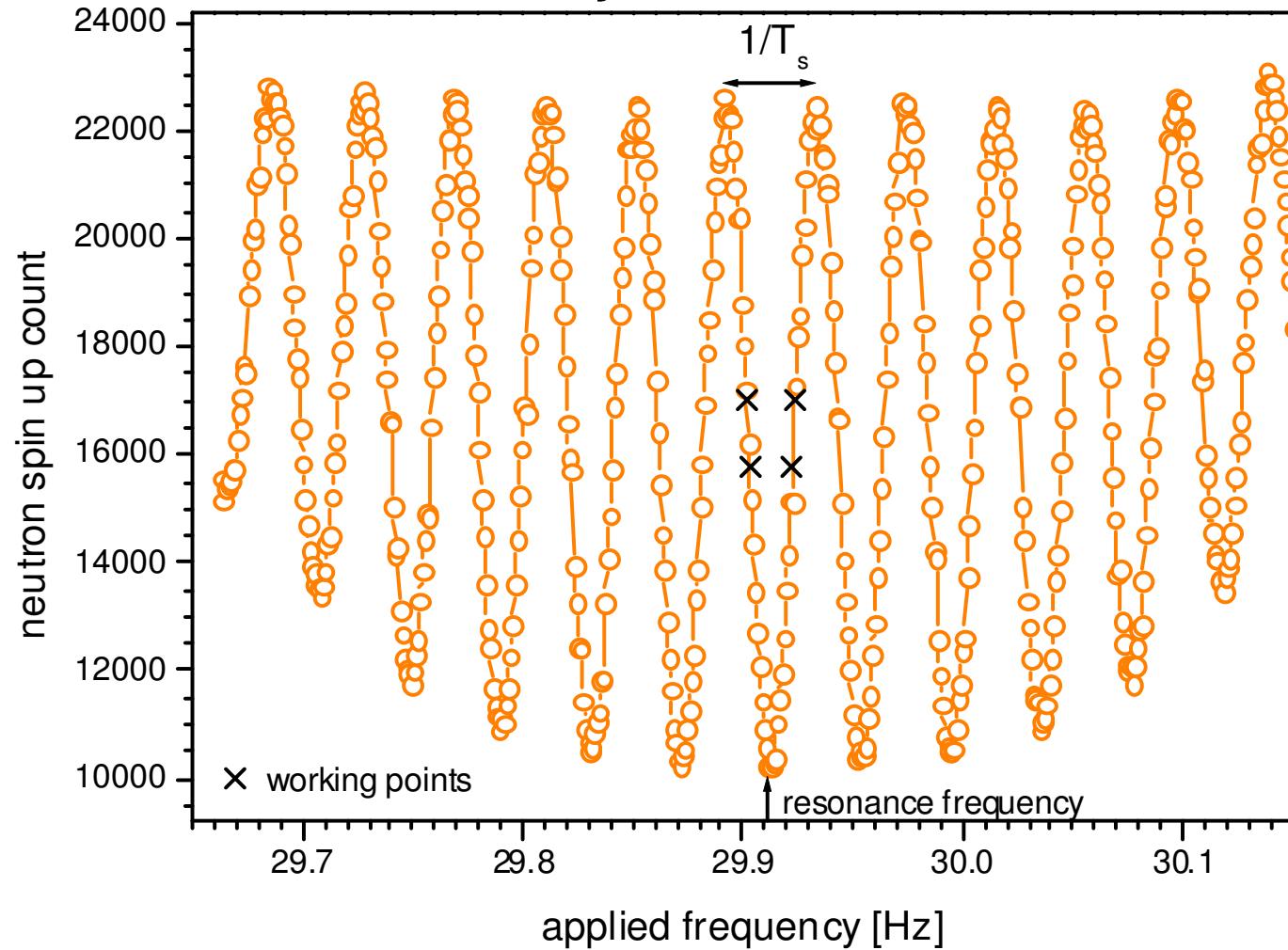
$$v_{\uparrow\downarrow} = \Delta E_{\uparrow\downarrow}/h = [-2B_0\mu_n + 2Ed_n]/h$$

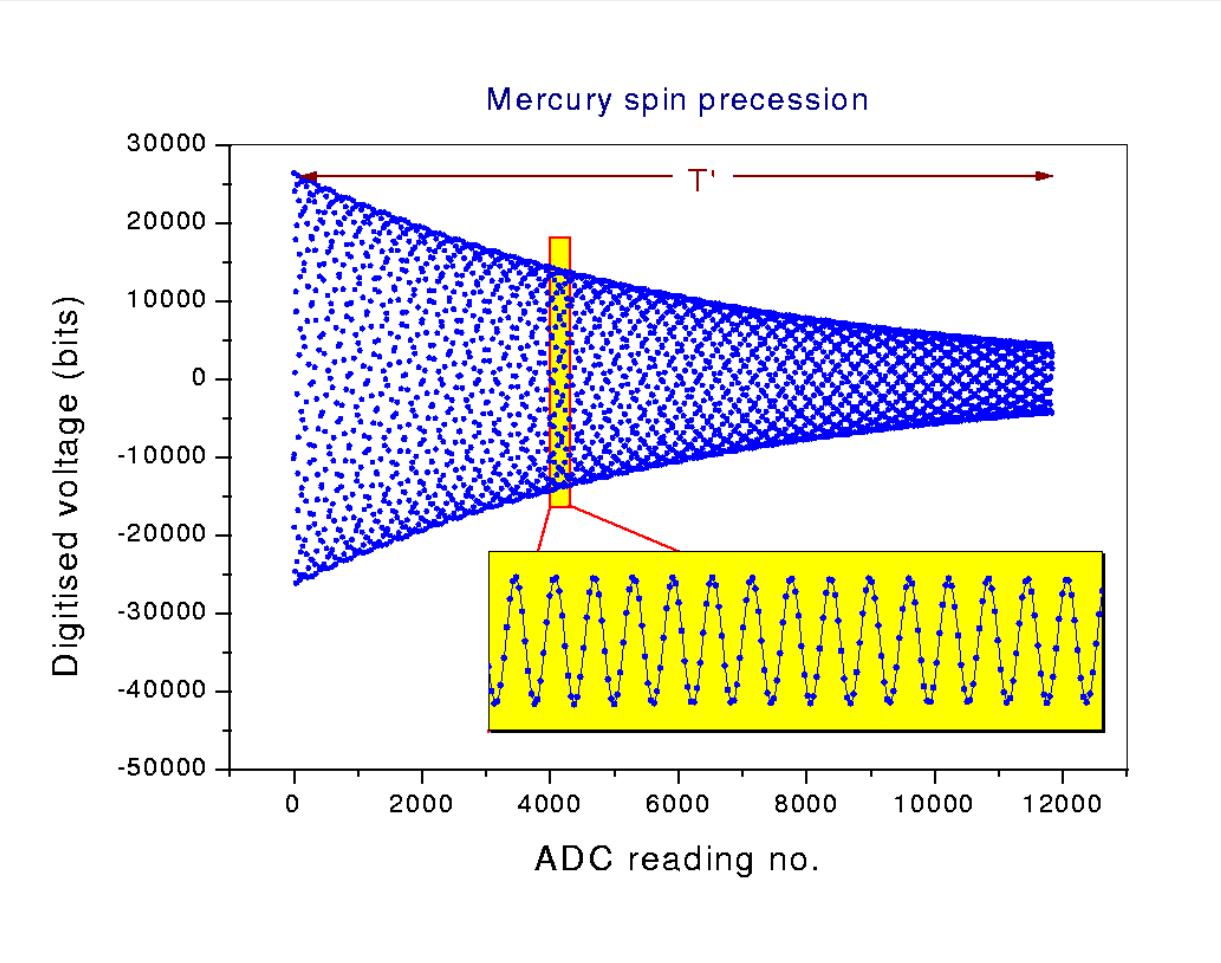
The difference is proportional to d_n and E :

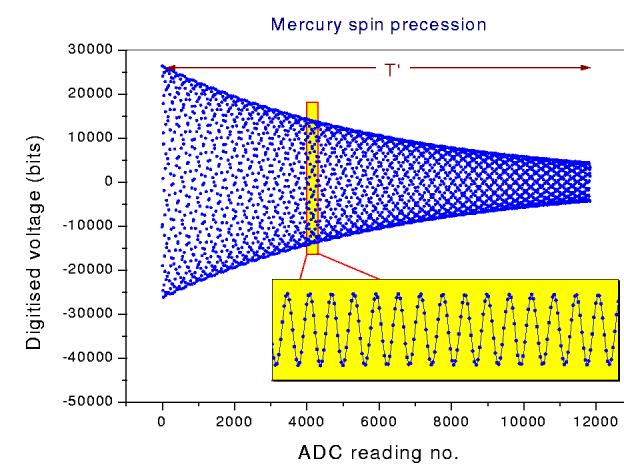
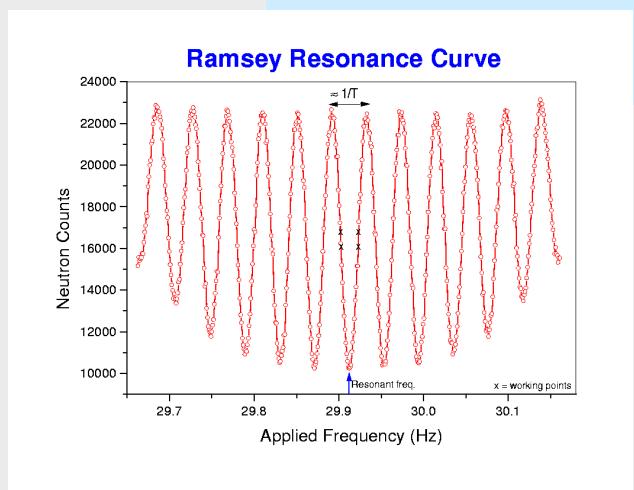
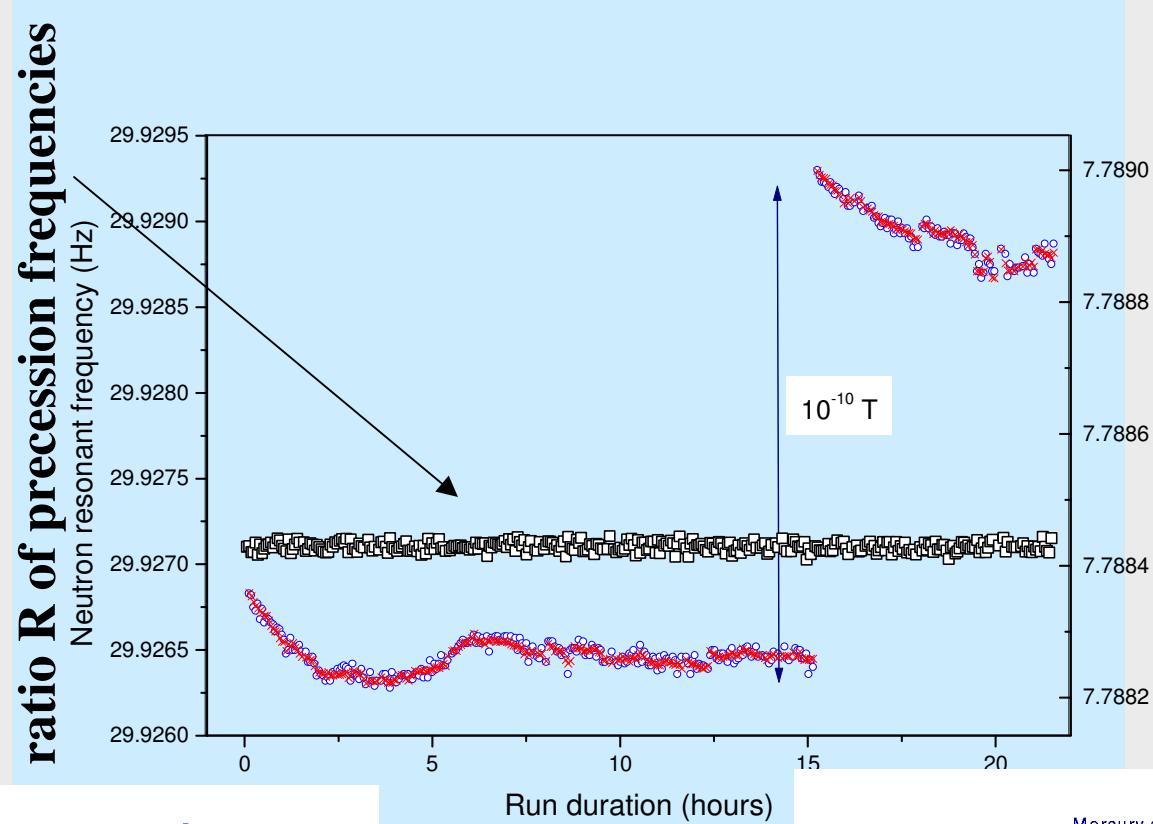
$$h(v_{\uparrow\uparrow} - v_{\uparrow\downarrow}) = 4E d_n$$



Ramsey Resonance Curve

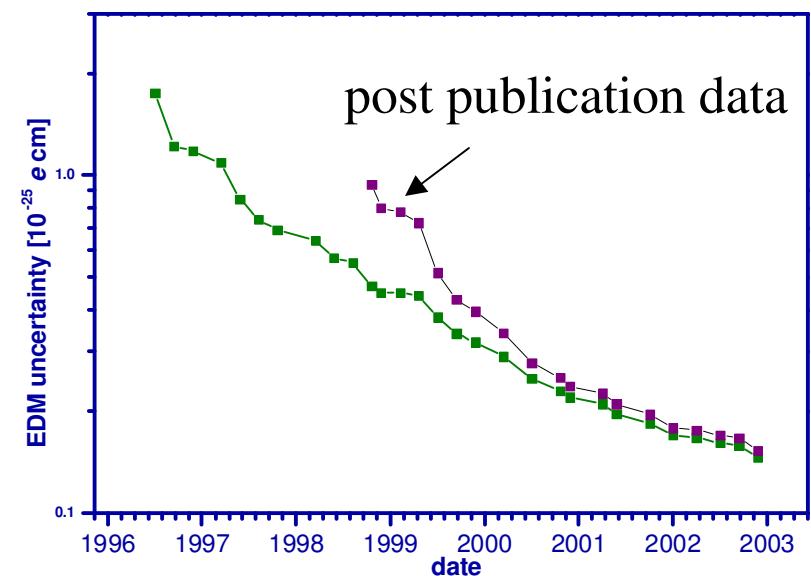
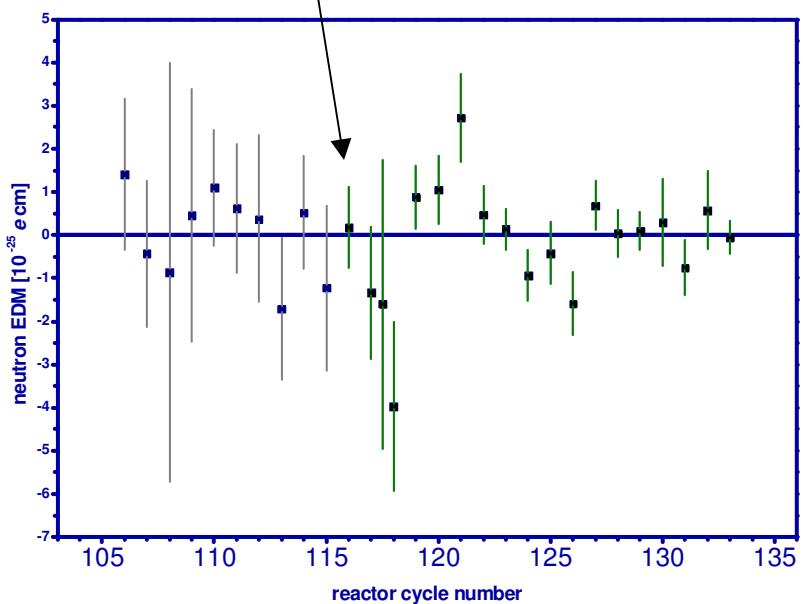
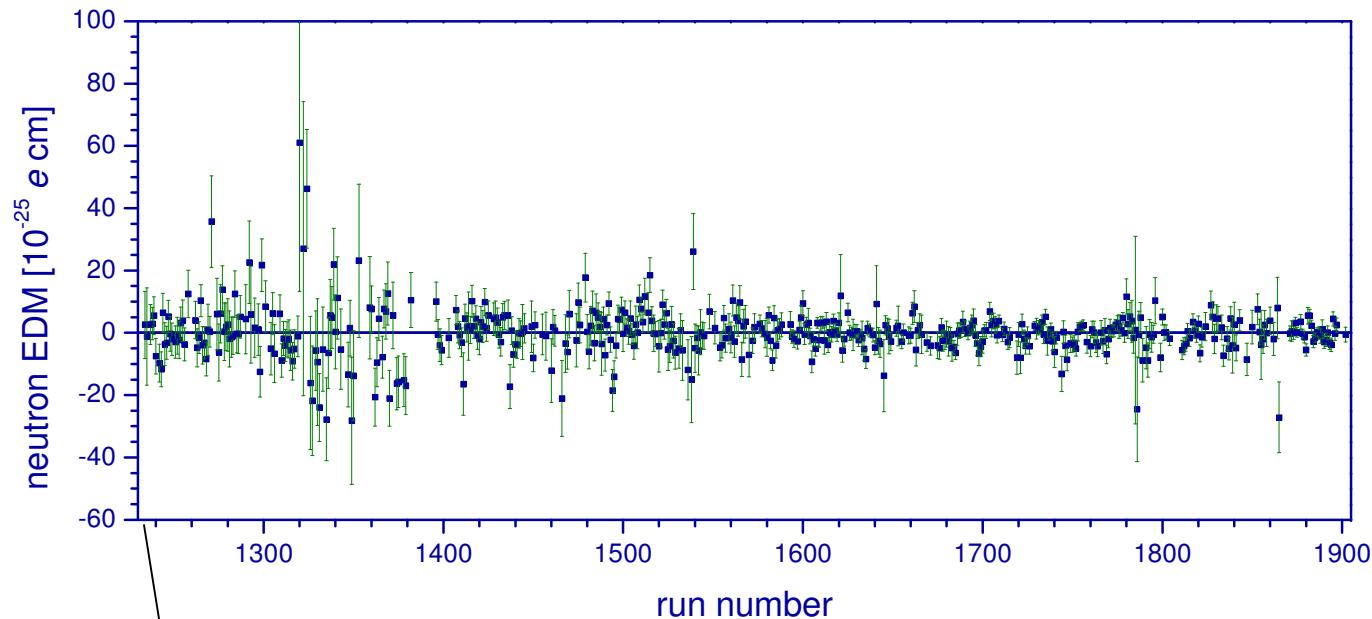






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statistical precision

$$\sigma(d_n) = 1.53 \times 10^{-26} \text{ e cm}$$

what about systematics ?

Geometric Phase Effect:

rotating magnetic field in the x-y plane
will affect precession of the neutron spin

ω_L shifts away from ω_0
(Ramsey-Bloch-Siegert shift)

$$\Delta\omega = \omega_L - \omega_0$$

$$\Delta\omega = \frac{\gamma^2 B_{xy}^2}{2(\omega_0 - \omega_r)}$$

field B_{xy} rotating at angular speed ω_r ,

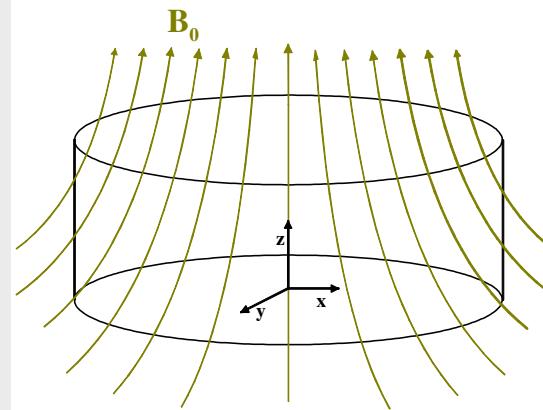
Geometric phase effects on the EDM measurement

Magnetic field component in the xy plane:

$v \times E$ effect

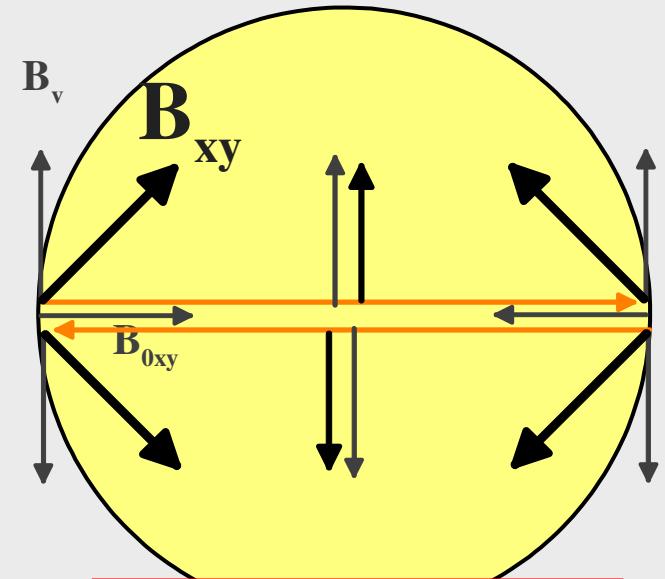
$$\mathbf{B}_v = \frac{\mathbf{E} \times \mathbf{v}}{c^2}$$

B_0 gradient



$$\mathbf{B}_{0xy} = -\left(\frac{\partial B_{0z}}{\partial z}\right) \frac{\mathbf{r}}{2}$$

rotating B field: B_{xy}

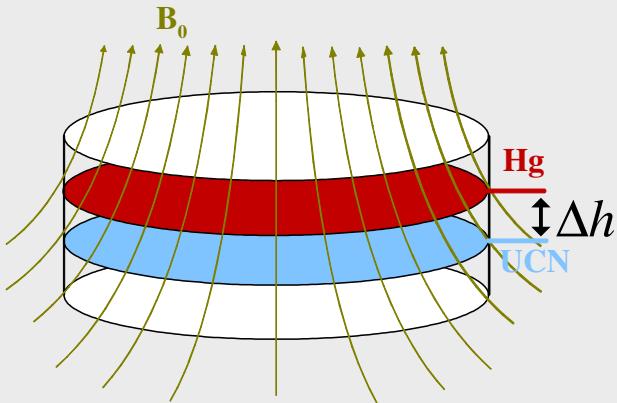


$$\mathbf{B}_{xy} = \mathbf{B}_{0xy} + \mathbf{B}_v$$

- we have a rotating B field
- we get a frequency shift $\propto E$
- we should see a false EDM signal $\propto dB/dz$

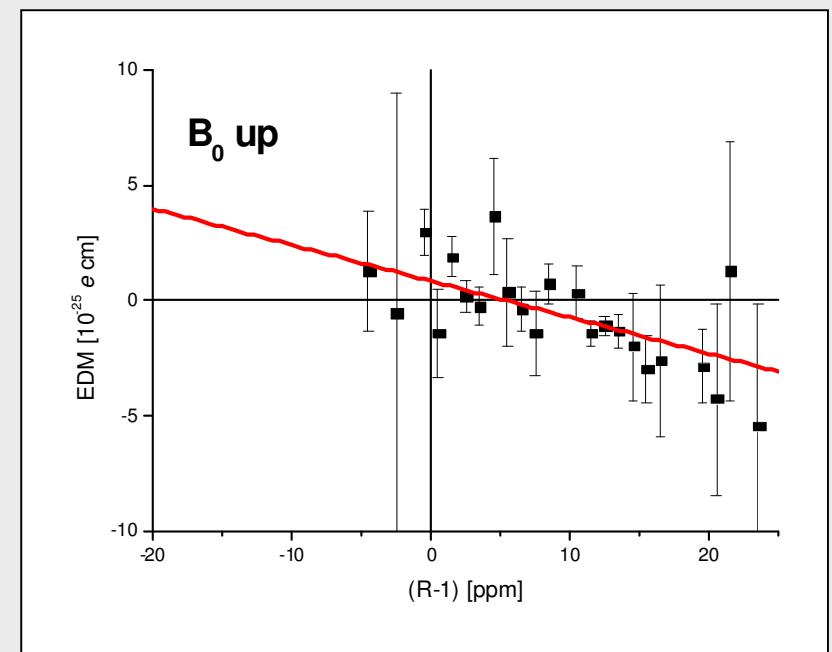
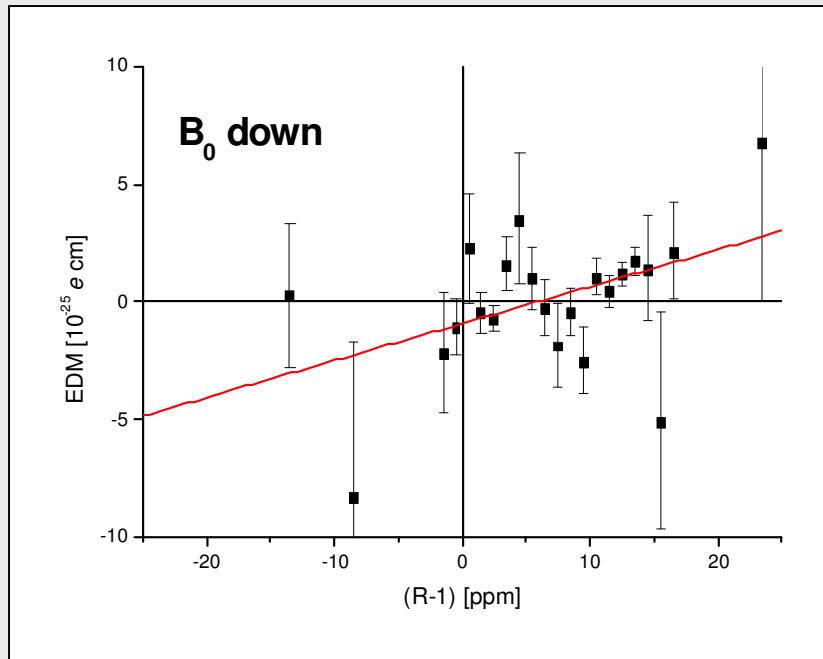
Ratio of precession frequencies:

$$R = \frac{\omega_n}{\omega_{Hg}} \frac{\gamma_{Hg}}{\gamma_n}$$



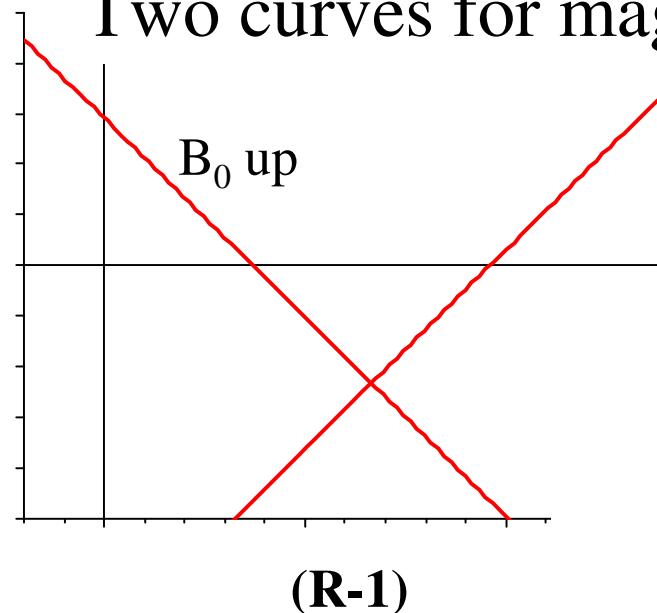
Magnetic field gradient will shift R away from 1: $dB/dz \propto (R-1)$

plot EDM vs measured (R-1) for two field directions



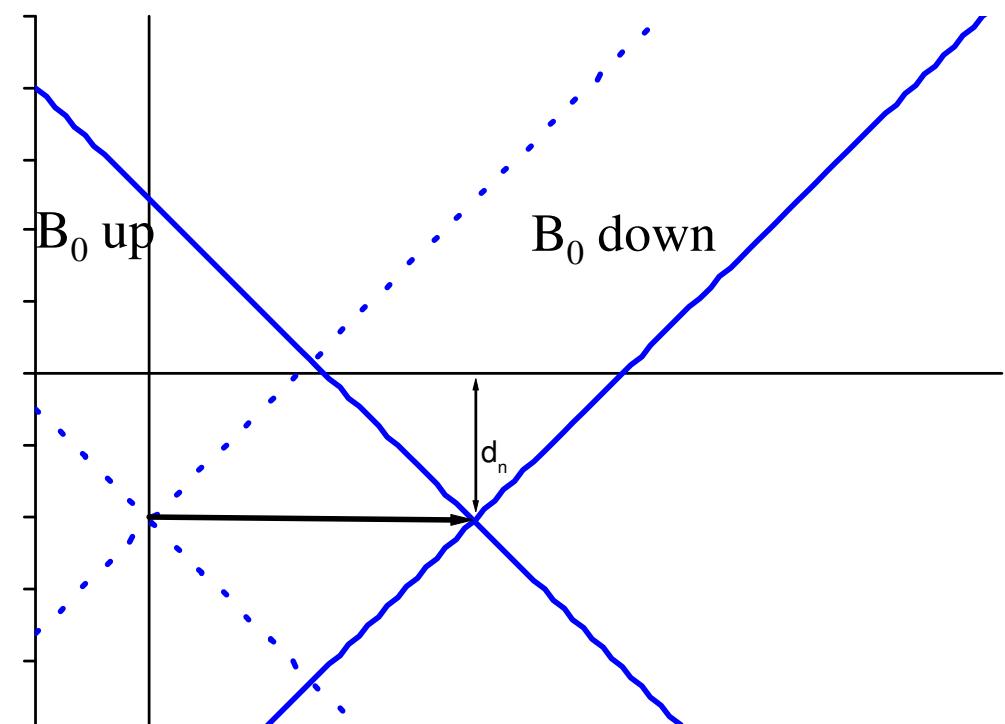
Two curves for magnetic field up and down

EDM



- geometric phase
- a finite EDM
- (R-1) shift

EDM

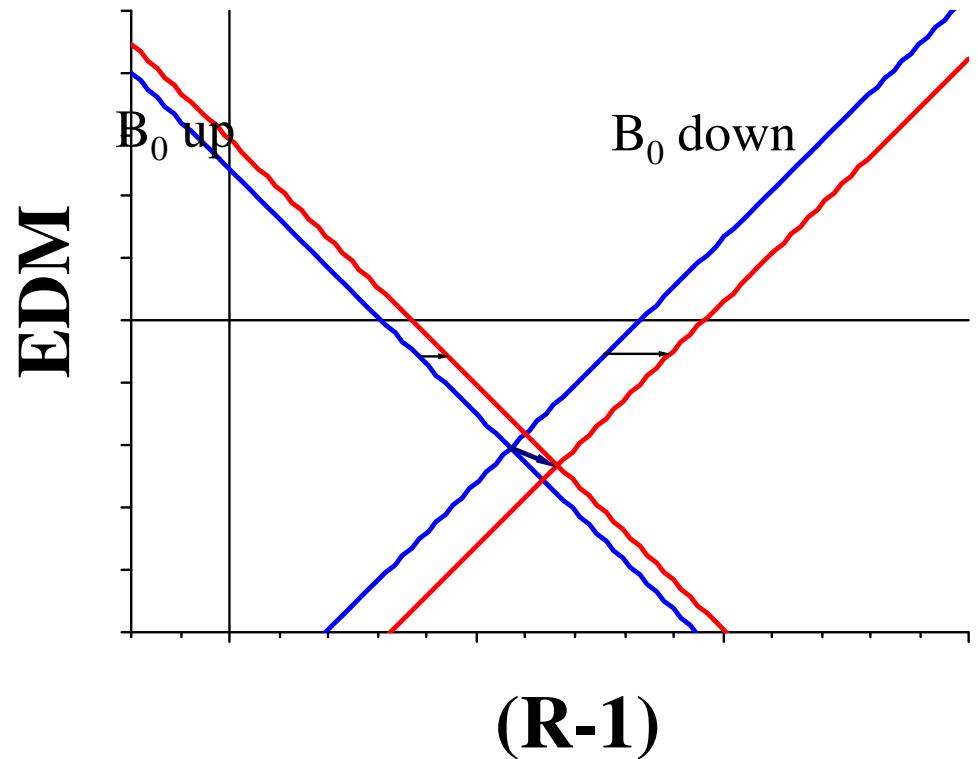


additional shifts in $(R-1)$ due to magnetic field:

one can:

- measure $(R-1)$ shifts
- model $(R-1)$ shifts

apply correction



precision in correction determines
the dominating systematic uncertainty

Uncertainties in measurement, order of $10^{-26} e \text{ cm}$

Statistical

GP - field gradients

Uncertainties in measurement, smaller than $10^{-27} e \text{ cm}$

$E \times v$ from translation

$E \times v$ from rotation

AC B fields from HV ripple

B fluctuations

E forces-distortion of bottle

Tangential leakage currents

light shift: direct

Light shift: GP effects

- Data taking completed
- Systematic studies completed

Both come with an uncertainty of
the order of $10^{-26} e \text{ cm}$

Final number on the limit on the nEDM
to be published soon

CryoEDM to start
running in summer 2006

